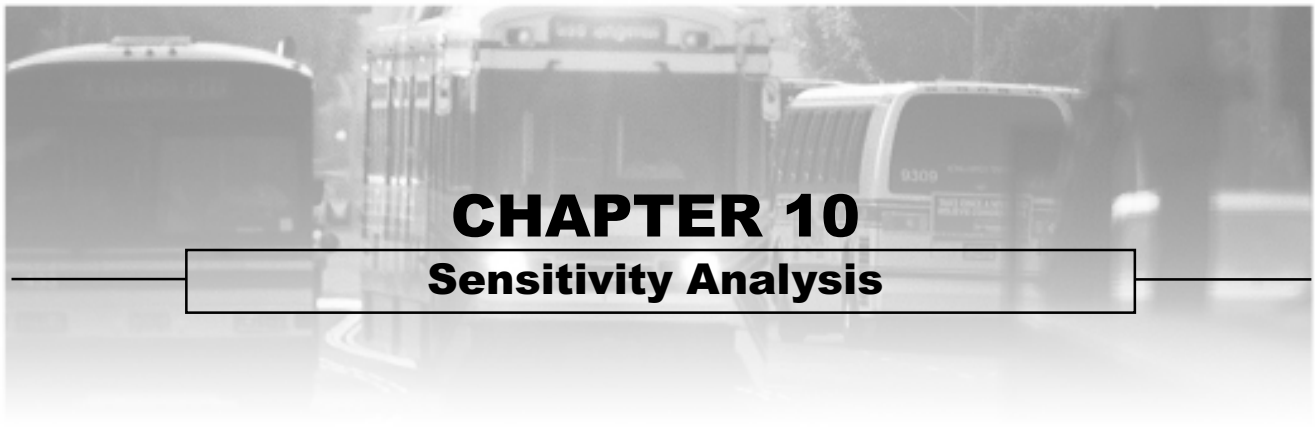

CHAPTER 10
Sensitivity Analysis

Introduction

This chapter explores the effects of varying some of the assumptions that were used to develop the investment requirement projections in Chapter 7. In any modeling effort, evaluating the validity of the underlying assumptions is critical. The results produced of Highway Economic Requirements System (HERS) and Transit Economic Requirements Model (TERM) are strongly affected by the values they are supplied for certain key variables. This chapter was added to the report to open up more of the modeling process, and to make the report more useful for supplementary analysis efforts.

There is a great deal of uncertainty about the appropriate values for the 20-year travel growth rates on which HERS and TERM rely. The highway and transit sections both show the impact that changing these assumptions would have on the investment requirement projections. The highway section of this chapter also explores a number of other variables, in part to show the impacts of some of the assumptions that were modified for this version of the report. The changes in the highway investment requirement methodology are discussed more fully in Appendix G.

One of the key parameters used in projecting investment requirements is the forecast rate of transit travel growth. The sensitivity of the estimated investment requirements to the growth rate forecast is analyzed by allowing three alternative growth rate inputs: 50 percent higher than the forecast, 50 percent below the forecast, and 100 percent below the forecast (i.e., zero transit passenger mile growth).

Highway Sensitivity Analysis

The accuracy of the investment requirements reported in Chapter 7 depends on the validity of the underlying assumptions used to develop the analysis. This section explores the effects that varying several key assumptions in the highway investment requirement analytical process would have on the Cost to Maintain Highways and Bridges and the Cost to Improve Highways and Bridges. While not discussed directly in this chapter, any changes in the projected investment requirements would also affect the "gaps" identified in Chapter 8 between projected spending and the investment requirement scenarios.

Alternative Travel Growth Assumptions

The States provide forecasts of future VMT for each individual HPMS sample highway section. As indicated in Chapter 7, the HERS model assumes that the forecast for each sample highway segment represents the level of travel that will occur if a constant level of service is maintained on the facility. This implies that VMT will only occur at this level if pavement and capacity improvements made on the segment over the 20-year analysis period are sufficient to maintain highway-user costs at 1997 levels. If HERS predicts that highway-user costs will deviate from baseline 1997 levels on a given highway segment, the model's travel demand elasticity features will modify the baseline VMT growth projections from HPMS.

Q. **Does the accuracy of the investment requirements projected by HERS depend on how accurately the travel forecasts in HPMS predict what future VMT growth will be?**

A. Not exactly. The HERS model assumes the travel forecasts in HPMS accurately predict what future VMT growth would be, if highway-user costs remained constant, rather than what future growth will be. This is a critical distinction.

The accuracy of the investment requirements depends on the accuracy of the travel forecasts in HPMS as modified by the travel demand elasticity features in HERS. At current funding levels, HERS predicts that highway-user costs will increase over time, so VMT will grow more slowly than the HPMS baseline forecasts, particularly in large urban areas. This concept is discussed in more detail in Appendix G.

The HERS model utilizes VMT growth projections to predict future conditions and performance of individual highway segments and to calculate future investment requirements. If the HPMS VMT forecasts **as modified by the HERS travel demand elasticity features** are overstated, the investment requirement projections may be too high. If the travel growth is underestimated, the investment requirement projections may be too low.

The effective VMT growth rates predicted by the HERS model could be off target if either the HPMS forecasts don't accurately predict the travel that will occur if a constant level of service is maintained, or if the travel demand elasticity procedures in HERS don't accurately predict the response that highway users will have to changes in costs. This section explores the impacts of modifying the HPMS forecasts. This is the equivalent of assuming that the HPMS forecasts don't actually predict the VMT that would occur at a constant level of service.

Increasing VMT Growth Projections

As indicated in Chapter 9, the State-supplied VMT growth projections in HPMS for 1997 to 2017 average 2.16 percent per year, well below the 2.84 average annual VMT growth rate observed from 1977 to 1997. The HERS model assumes that the 2.16 percent composite VMT growth projection in HPMS represents the growth that will occur at a constant level of service. If this forecast understates future growth, the investment requirements will be higher than predicted.

Exhibit 10-1 shows the impact on investment requirements of assuming that the VMT growth that would occur at a constant level of services will be 2.84 percent annually (matching the actual growth rate over the last 20 years), rather than the 2.16 percent rate derived from the HPMS forecasts. This is achieved by factoring up the growth rates entered into the HERS model for each section by 31.5 percent. Modifying the travel growth projections in this fashion would increase the Cost to Maintain Highway and Bridges by 15.5 percent. Increased VMT would increase the rate of pavement deterioration, as well as increase the share of resources that HERS would recommend using for capacity expansion. Both these factors would tend to increase the investment required to maintain condition at 1997 levels. The Cost to Improve Highways and Bridges would increase by 14.1 percent based on this change in assumptions. The increased travel would increase the number of pavement and capacity projects that HERS would find to be cost-beneficial.

Exhibit 10-1

Impact of Alternate VMT Growth Assumptions on Investment Requirements

	Cost to Maintain Highways & Bridges		Cost to Improve Highways & Bridges	
	($ Billions)	Percent Change	($ Billions)	Percent Change
Chapter 7 Baseline	**56.6**		**94.0**	
Overall VMT Growth Rates increased from 2.16% to 2.84%	65.4	15.5%	107.3	14.1%
VMT Growth Rates in Urbanized Areas>1,000,000				
Decreased 10% from 1.86 to 1.68%	55.7	-1.6%	92.9	-1.1%
Decreased 20% from 1.86 to 1.49%	55.3	-2.4%	92.1	-2.0%
Decreased 50% from 1.86 to 0.93%	53.5	-5.6%	89.5	-4.7%
Decreased 100% from 1.86 to 0%	50.4	-11.0%	86.1	-8.3%

Source: Highway Economic Requirements System (HERS).

Reducing VMT Growth Projections in Large Urbanized Areas

Exhibit 10-1 also shows the effects of reducing the initial travel growth projections for all HPMS sections in areas over 1 million in population by 10 percent, 20 percent, 50 percent, and 100 percent. As indicated in Chapter 9, the average annual VMT growth rate for HPMS sections in large urbanized areas is 1.86 percent. If this value actually represents the travel growth that would occur at a rising level of service, factoring down the VMT growth rates could reduce them to the level that would occur at a constant level of service, which HERS needs to properly perform its travel demand elasticity adjustments.

Factoring down the initial travel projections for all HPMS sections in large urbanized areas by 10 percent would reduce the average annual VMT growth projection from 1.86 percent to 1.68 percent. This would reduce the Cost to Maintain Highways and Bridges by 1.6 percent, and reduce the Cost to Improve Highways and Bridges by 1.1 percent. A 20 percent reduction would change the average annual VMT growth projection in large urbanized areas to 1.49 percent, and would reduce the Cost to Maintain Highways and Bridges and the Cost to Improve Highways and Bridges by 2.4 percent and 2.0 percent respectively. If it is assumed that no travel growth will occur in large urbanized areas at all, unless user costs decline, then the Cost to Maintain Highways and Bridges would be 11.0 percent lower and the Cost to Improve Highways and Bridges would be 8.3 percent lower. (Note that investment in large urbanized areas only would be much more heavily affected than overall investment in all areas, and would decline 37.9 percent and 29.2 percent respectively.)

If reductions in highway travel growth coincided with increases in transit PMT growth, this would increase overall transit investment requirements, offsetting to some extent the lowered highway investment requirements. The effects of changing transit travel growth assumptions are discussed later in this chapter.

Q. **Why does reducing VMT growth rates in urbanized areas over 1 million in population have a smaller impact on investment requirements than raising the VMT growth rates for all highway sections?**

A. Of the total investment requirements for the Cost to Maintain Highways and Bridges and the Cost to Improve Highways and Bridges, only 28.5 percent and 29.1 percent respectively are for highway improvements in urbanized areas over 1 million. Therefore, over 70 percent of the baseline investment requirements would not be affected by a reduction in VMT growth rates that applies only to highway sections in large urbanized areas.

Other Alternative Assumptions

As in the case with travel growth projections, changing other key variables can have a significant impact on the investment requirement results. Exhibit 10-2 shows the impact that changing certain variables would have on the Cost to Maintain Highways and Bridges and the Cost to Improve Highways and Bridges. The individual changes are discussed in more detail below.

Exhibit 10-2

Impact of Other Alternate Assumptions on Investment Requirements

	Cost to Maintain Highways & Bridges		Cost to Improve Highways & Bridges	
	($ Billions)	Percent Change	($ Billions)	Percent Change
Chapter 7 Baseline	**56.6**		**94.0**	
Turn on High Cost Lane Feature	72.9	28.7%	129.7	38.0%
Change Elasticity Values to 1997 C&P Levels	59.4	4.9%	93.2	-0.8%
Turn off Emissions Module	56.7	0.1%	95.0	1.1%
Value of time: Increase 100 percent	60.4	6.6%	98.5	4.9%
Value of time: Reduce 50 percent	56.8	0.3%	90.4	-3.8%
Value of life: Increase 100 percent	57.8	2.1%	94.4	0.5%
Value of life: Reduce 50 percent	56.5	-0.2%	93.8	-0.2%

Source: Highway Economic Requirements System (HERS).

High Cost Lanes

For each highway section in HPMS, States code a Widening Feasibility rating. In this report, it has been assumed that highway sections cannot be widened beyond the width specified as feasible by the States. However, the investment requirement analysis in previous C&P reports treated the widening feasibility rating as a measure of the number of lanes that could be added at "normal" cost. In previous reports, it was assumed that if adding additional lanes was justified, they could be added at "high" cost, representing the cost required to double-deck a freeway, build a parallel route, or acquire expensive right-of-way. The decision to turn off the high-cost lane feature in HERS for this report is explained in Appendix G.

Turning on the high-cost lane feature would increase the Cost to Improve Highways and Bridges by 38.0 percent. This feature allows HERS to add additional lanes in congested areas. While these lanes are expensive, the model would consider them to be cost-beneficial in many situations.

Turning on high-cost lanes would increase the Cost to Maintain Highways and Bridges by 28.7 percent. This occurs because the model would shift a greater percentage of investment towards capacity improvements, since there would be more attractive widening projects to choose from. As explained in Chapter 7, the Highway Maintain Conditions scenario represents a cost-beneficial mix of investments that is expected to maintain average IRI, but also includes capacity projects that meet the same minimum BCR cutoff point.

Elasticity Values

The travel demand elasticity values were increased in this report to -1.0 for short term elasticity with an additional -0.6 (total -1.6) for long term elasticity. [See the discussion of elasticity in Chapter 7]. In the 1997 C&P report, values of -0.8 and -0.2 (total -1.0) were used. The rationale behind this change is explained in Appendix G.

Setting the elasticity values back to the levels used to develop the 1997 C&P report would increase the Cost to Maintain Highways and Bridges by 4.9 percent. As indicated in Chapter 7, highway-user costs are projected to increase overall under the Highway Maintain Conditions scenario. Therefore, the elasticity procedures in HERS tend to suppress travel growth at this level of investment. Reducing the elasticity values back to the levels used in the 1997 C&P report would allow additional travel to occur, thus boosting the investment requirements.

The opposite effect can be observed in the Cost to Improve Highways and Bridges. Under the Highway Maximum Economic Investment scenario, highway users are projected to decline. At this level of investment, the elasticity procedures in HERS tend to induce travel growth. Therefore, reducing the elasticity values back to the levels used in the 1997 C&P report would reduce the amount of induced travel, and reduce the investment requirements.

Emissions Module

The HERS model now factors in the societal costs of emissions into its benefit-cost analysis of highway improvements. As discussed in Appendix G, the emissions module in HERS is based on older research. The impact of emissions costs on the investment requirements may change in the future, as the HERS emissions equations are enhanced.

Turning off the emissions module in HERS would increase the Cost to Maintain Highways and Bridges by 0.1 percent and increase the Cost to Improve Highways and Bridges by 1.1 percent. When the model doesn't consider the societal costs of emissions, it finds more potential improvements to be cost beneficial.

Value of Time

The value of time in HERS was developed using a standard methodology adopted by the Department of Transportation. This methodology provides consistency between different analyses performed within the Department. However, there is a great deal of debate about the appropriate way to value time, and no single methodology has been uniformly accepted by the academic community, or within the Federal government.

Doubling the value of time in HERS would increase the Cost to Maintain Highways and Bridges by 6.6 percent and increase the Cost to Improve Highways and Bridges by 4.9 percent. Increasing the value of time causes HERS to consider more widening projects that reduce travel time costs cost beneficial. The proportion of capacity projects implemented as a percentage of total projects would increase, causing the Cost to Maintain Highways to rise also.

Reducing the value of time by 50 percent would cause a slight 0.3 percent increase in the Cost to Maintain Highways and Bridges, and a 3.8 percent reduction in the Cost to Improve Highways and Bridges. The slight increase in the Cost to Maintain Highways and Bridges is caused by the change in the mix of projects that are implemented.

Value of Life

HERS uses $2.7 million for the value of life, which is the Department of Transportation's standard value for use in benefit-cost analyses. As in the case with the value of time, there is a great deal of debate about the appropriate value, and no single dollar figure has been uniformly accepted by the academic community, or within the Federal government.

Doubling the value of life in HERS would increase the Cost to Maintain Highways and Bridges by 2.1 percent and increase the Cost to Improve Highways and Bridges by 0.5 percent. HERS would find a few more projects to implement on the basis of their increased safety benefits, if the value of life were increased. HERS would also change the mix of recommended improvements, favoring those that reduce crash costs over those that primarily gain their benefits by improving pavement quality. This effect tends to cause the Cost to Maintain Highways and Bridges to increase.

Reducing the value of life by 50 percent would reduce the Cost to Maintain Highways and Bridges by 0.2 percent and reduce the Cost to Improve Highways and Bridges by 0.2 percent. Some marginal projects that were justified based on potential reductions in crash rates they would cause would not be implemented if the value of life was reduced.

Transit Sensitivity Analysis

One of the most important parameters used by TERM in forecasting transit investment needs is the projected growth rate in transit passenger miles traveled (PMT). This forecast is obtained from metropolitan planning organizations (MPOs) in large urbanized areas, most of which make forecasts about transit PMT and auto VMT growth as part of the regional transportation planning process. The average annual growth rate in PMT from the most recently available MPO forecasts, used in this report, is 1.90 percent.

The assumed passenger travel growth rate has several important effects on the estimates of investment requirements. The effect is most important for Asset Expansion. The forecast travel growth rate is the primary factor in determining the need for system expansion in order to accommodate increased transit usage while maintaining a constant degree of vehicle utilization. A larger growth rate also affects the degree to which crowded systems become even more so, requiring even more investment to achieve Performance Improvement. On the other hand, the growth rate does not affect the need for the replacement and rehabilitation of the existing capital stock as it wears out.

In order to examine the sensitivity of the estimated transit investment requirements to forecast transit growth rates, TERM was run using the following three alternative scenarios:

1) PMT growth is 50 percent greater than the forecast levels
2) PMT growth is 50 percent less than the forecast levels
3) There is no growth in transit PMT.

The effect of varying the growth rate is shown in Exhibit 10-3. Adjusting the growth rate has a significant effect on the estimated investment requirements, though the effect is greater under the **Maintain Conditions and Performance** scenario. Under the Maintain scenario, each 1 percent change in the growth rate causes a 35 to 40 percent change in investment requirements, while the same change in the growth rate changes the Improve scenario investment requirements by 25 to 30 percent. The smaller sensitivity under the Improve scenario is due to the greater replacement and rehabilitation expenditures which are necessary for condition improvements. Note that even under conditions of no growth in passenger miles, major investment would still be required in order to maintain the current system, with still greater expenditures to improve conditions and performance relative to current levels.

Exhibit 10-3

Impact of Alternative PMT Growth Rates on Transit Investment Requirements

	Annual Cost to Maintain Conditions & Performance		Annual Cost to Improve Conditions & Performance	
Annual PMT Growth Rate	(Billions of $)	Percent Change	(Billions of $)	Percent Change
Baseline (1.90%)	**10.8**	**---**	**16.0**	**---**
Increased 50% (to 2.85%)	13.0	20.7%	18.4	14.7%
Decreased 50% (to 0.95%)	8.8	-18.0%	14.1	-12.4%
Decreased 100% (to 0%)	7.0	-34.8%	12.2	-24.0%

Source: Transit Economic Requirements Model.